MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

ERT3036 – ADVANCED ROBOTICS

(RE)
(OPEN BOOK EXAMINATION)

07 FEBRUARY 2023
09:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **6 pages** including cover page with **4 Questions** only.

2. Attempt **ALL** questions. The distribution of the marks for each question is given.

3. Please write all your answers clearly in the answer booklet provided.

Question 1

On the 19th October 2015, the Prime Minister of Singapore Mr. Lee Hsien Loong interacting with Olivia at the official opening of Fusionopolis Two. Olivia is a differentially driven wheeled mobile robot as shown in Figure Q1a.

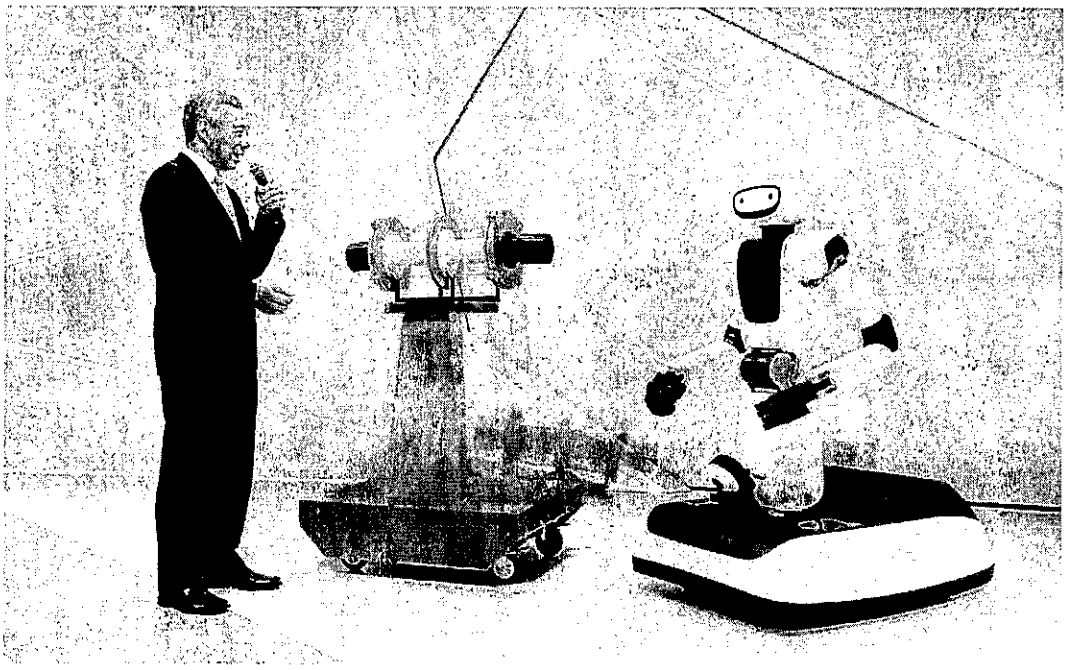


Figure Q1a The Prime Minister of Singapore was interacting with Olivia, a robot receptionist.
(Picture source: http://www.straitstimes.com/singapore/ntu-debuts-robots-nadine-and-edgar-5-other-impressive-singapore-robots)

(a) The wheel radius of Olivia is 6 cm. The two wheels are separated by 40 cm. For each complete revolution of the wheel, the quadrature encoder gives 360 pulses. q_1 and q_2 are the incremental encoder reading for wheel 1 (left wheel) and wheel 2 (right wheel) respectively. The coordinates of wheel 1 (left wheel) is resting at (0,0) at t=0 with an orientation of ϕ = 0 radian.

(i) Calculate the pulses measured by q_1 and q_2 respectively when the robot is making a 30 degrees turn in the clockwise direction with an instantaneous radius of curvature, R_i = 8 m. [4 marks]

(ii) Calculate the coordinates of point P which is the mid-point between the two wheels along the differential drive axis. [6 marks]

(iii) The mobile robot will continue to rotate in the clockwise direction with an instantaneous radius of curvature, R_i = 10 m. Find the ratio of the wheel velocities, v_2/v_1, where v_1 and v_2 are the linear wheel velocities respectively. [3 marks]

Continued ...

(b) Figure Q1b shows a mobile robot for mapping designed by FET student. The following information is available for this robot.

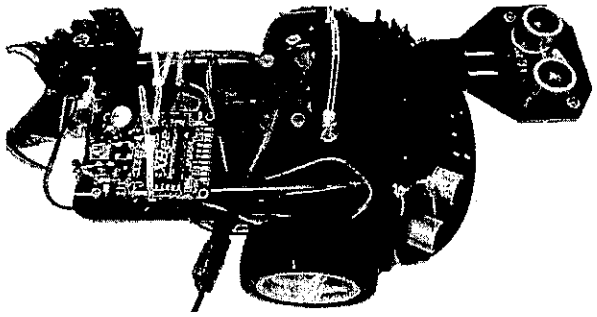


Figure Q1b. A mobile robot for mapping

Width of robot, w = 0.2m

Length of robot, L = 0.5m

Current position, P = (1m, 3m)

Global position, G = (5m, 1m)

Obstacle **1** position, $T1$= (3m, 2m)

Radius of $T1$, $R1$ = 0.5m

Obstacle **2** position, $T2$= (1m, 5m)

Radius of T2, $R2$ = 0.6m

Find the heading direction of this robot by using Artificial Potential Field **(APF)** method.

[12 marks]

Continued ...

Question 2

(a) A 5-link biped robot in frontal plane is shown in **Figure Q2(a)**. Each link is modeled as a point mass at the centre of mass of the link.

(i) When the biped robot is standing using one leg, the zero moment point (ZMP) is located at position y_{ZMP} in the y-z plane. Express y_{ZMP} as a function of point mass (M_1 to M_5) and distance of point mass from the z-axis (y_1 to y_5 and $y_1 = y_2$).

[5 marks]

(ii) Discuss whether y_3 should be at the left of the ZMP or to its right when M_1 and M_2 are vertical along the z-axis.

[4 marks]

(iii) If M_3 also represents total upper body mass, modify the equation found in part (i) to include the acceleration in the y-axis for M_3, $\ddot{y}$, when the biped robot is walking (i.e. switching legs). Z_c is the height of M_3 from the ground.

[4 marks]

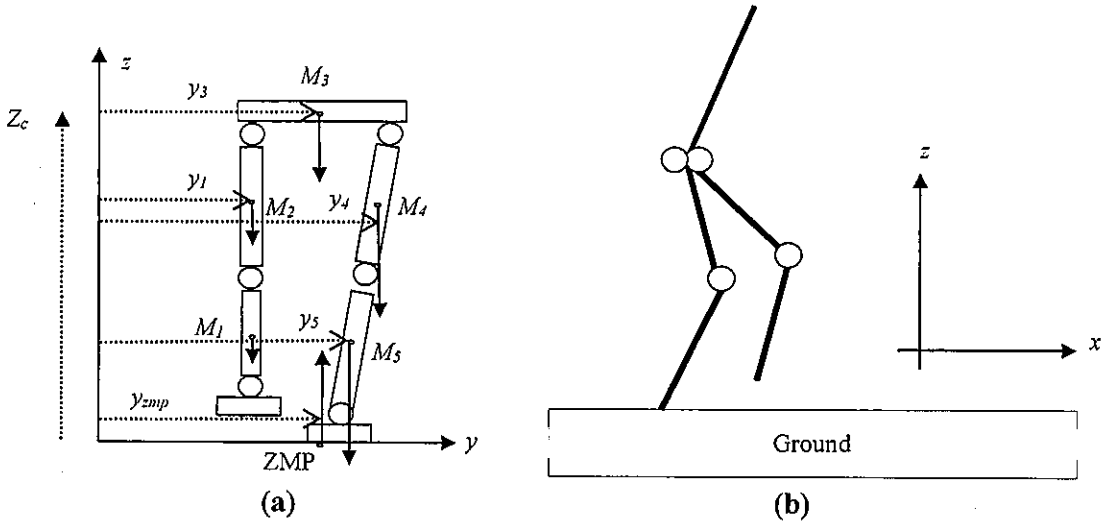


Figure Q2. A model of 5-link robot in **(a)** frontal plane and **(b)** sagittal plane

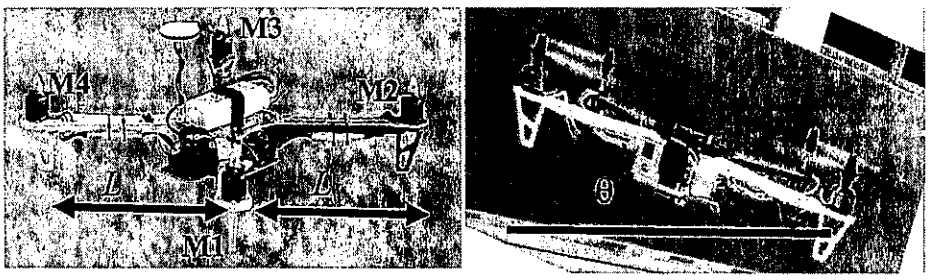
(b) The five-link biped robot is represented in the sagittal plane as in **Figure Q2(b).** Describe the mathematical steps to be taken in deriving its dynamic equation.

[12 marks]

Continued ...

Question 3

(a) A DJI F450 quadcopter is shown in **Figure Q3** with the mass, $M = 0.5$kg, $k = 6\text{x}10^{-8}$ N/ (rpm)^2 and $g = 9.81$ m/s^2.



(i) **(ii)**

Figure Q3. (i) The quadrotor is hovering. **(ii)** The quadrotor is moving to the right *(Picture Source: http://www.rcgroups.com/forums/showthread.php?t=1901564)*

(i) When all four motors are rotating at same speed, ω , the quadrotor is hovering. Find ω in rpm.

[5 marks]

(ii) When the quadrotor is making an angle θ with the horizontal plane, it moves along the x-axis to the right as shown. If the gravity force is still compensated with all the rotors are having the same speed at ω_m, and the acceleration in the x direction, a_x is 2m/s^2, find the angle θ and ω_m.

[8 marks]

(iii) Briefly describe how you can change from hovering to moving to the right for this quadrotor.

[5 marks]

(iv) When $T_1 = T_2 + \Delta T$, $T_2 = T_4$ *and* $T_3 = T_2 - \Delta T$, how much time is required to reach the desired tilt angle as in **(b)** when the moment of inertia for the quadrotor is $J = 0.0025$ kgm^2, $L = 0.225$m and $\Delta T = 5.07\text{x}10^{-4}$ N?

[7 marks]

Continued ...

Question 4

(a) A kindergarten in your community is going to introduce NAO robot, shown in **Figure Q4(a)**, as the Social Assistive Robot (SAR) programme in an attempt to reduce human workload. You are requested to elaborate on some ethics issues or potential problems on this initiative before its actual implementation.

[10 marks]

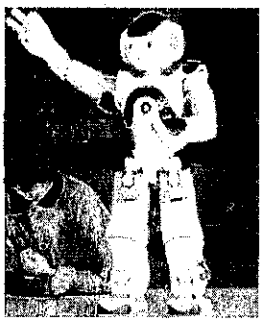


Figure Q4(a). NAO robot
(Picture source: https://thebrainary.com/blog/waikiki-primary-school-in-the-west-australian-newspaper-talking-about-their-new-nao-robot/)

(b) Professor Michael Anderson from the University of Hartford and Professor Susan Anderson from the University of Connecticut collaborated to create the first ethical robot in 2010. The ethical architecture is based on the four robotic laws introduced by Issac Asimov's Laws of Robotics. State these laws.

[6 marks]

(c) The Q table for a Q-learning robotic system is shown in **Table Q4 (b)**. At this point of time, the learning rate, $\alpha = 0.3$, and the discount rate, $\gamma = 0.2$. All transitions have reward **R = 0** except transition from **B** to **D** with a reward, **R = 20** and transition from **D** to **D** with a reward of **R = 30**. Transition from **A** to **B**, **Q (A, B) = 10** at the moment.

Find the final **Q** values for the transitions in sequence of From **A** to **B**, **B** to **D** and **D** to **D**. **[9 marks]**

Table Q4(b). Q Table for Question 4(b)

Final / Source	A	B	C	D
A	0	10	4	2
B	5	2	0	7
C	2	2	1	3
D	1	3	0	2

End of Page